OMPS Nadir Mapper Level 2 Description

1. Purpose and Scope

The purpose of this document is to provide an overview of the OMPS-NPP Nadir Mapper Level 2 data product format for its users. The NMTO3-L2 APP retrieves total column ozone from measured normalized radiances contained with the L1B file.

2. Nadir Mapper

The OMPS nadir instrument is composed of two spectrometers that share the same telescope. A dichroic filter downstream of the telescope redirects photons into either the NM or the Nadir Profiler (NP) spectrometer. The telescope itself has a 110° total across-track field of view (FOV), resulting in 2800 km instantaneous coverage at the Earth's surface; this is sufficient to provide daily full global coverage at the equator for the NM sensor. The telescope includes a pseudo depolarizer [McClain et al., 1992] designed to minimize the system's sensitivity to incoming polarization. The dichroic filter is optimized to reflect most of the 250–310 nm light to the NP spectrometer and transmit most of the 300–380 nm light to the NM spectrometer.

Once split, the light from the NM spectrometer is dispersed via a diffraction grating onto one dimension of a two dimensional charge-coupled device (CCD) located at the spectrometer's focal plane. The second dimension reflects the cross-track spatial coverage provided by the slit aperture and optics. The CCD consists of 340 pixels along the spectral dimension and 740 pixels in the across-track spatial dimension.

Measurements meeting the 300–380 nm wavelength range specification required by the NM sensor are obtained by illuminating 196 of the 340 pixels in the spectral dimension. In the across-track dimension, 708 pixels are illuminated. For nominal operations, the pixel signals are summed into 35 separate "macropixel" FOVs; all but the two outer FOVs contain 20 pixels per macropixel; the left outermost macropixel contains 26 pixels, while the right outermost contains 22. Since the readout of the CCD is split in the center, measurements comprising the central FOV are actually split (although not symmetrically). Rather than rebinning these measurements in ground processing, they remain split, resulting in 36 cross-track FOVs. In this case, the central two FOVs comprise 12 pixels (30× 50km) and 8 pixels (20 × 50 km), respectively.

Because macropixels are constructed in programmable flight electronics, the OMPS nadir temporal (along-track) and spatial (across-track) resolutions are highly configurable. High-resolution measurements, approximately 10 km× 10 km at nadir, have been routinely collected

1 day per week for the first 2 years of the mission. To remain within the telemetry bandwidth constraints, a set of only 59 wavelengths was selected; this selection still allows retrievals of total column ozone and other quantities (such as SO_2).

3.0 Algorithm Background

The basic algorithm used for the V2.1 dataset is NASA's V8.5 total column retrieval algorithm, which uses 2 wavelengths (317.5 and 331.2 nm under most conditions, and 331.2 and 360 nm for high ozone and high solar zenith angle conditions). The longer of the two wavelengths is used to derive effective cloud fraction (fc) based on the Mixed Lambert Equivalent Reflectivity (MLER) model [Ahmad et al. 2004] that was developed to model the effect of clouds on Rayleigh scattering. When fc becomes less than zero or when there is snow/ice, we assume that no cloud is present and use the Lambert Equivalent Reflectivity (LER) model described by Ahmad et al. [2004] to derive the clear scene reflectivity R. When fc exceeds 1, we assume 100 percent cloud cover and derived cloud reflectivity using the LER model. Given the fc/R, the shorter (stronger ozone-absorbing) wavelength is used to derive total ozone.

An important difference between the V8.5 algorithm and previous versions, as well with the archived TOMS dataset, is the assignment of effective cloud height. It has been assumed in the previous algorithms that the absorption of backscattered solar radiation essentially stops at the cloud-top level when the clouds are optically thick. To estimate the total column amount, the "un-measured" column below the cloud-top (computed using climatology) is added to the measured column. Recent analysis of the OMI data in conjunction with CloudSat radar data [Vasilkov et al. 2008] indicates that this assumption is invalid. Mie scattering calculations using CloudSat data indicate that in all cloudy scenes, including deep convective clouds, the UV radiation received at the satellite is sensitive to the ozone column below the nominal cloud-top pressure reported by thermal infrared sensors such as MODIS. Analysis shows that photons actually penetrate some distance into a cloud. In V8.5, we use a climatology of the Optical Centroid Cloud Pressure (OCCP) inferred from Rotational-Raman Scattering (OMCLDRR) to derive the total ozone column. The climatology was developed using OCCP retrievals from the Ozone Monitoring Instrument (OMI) onboard the Aura satellite. Since the pressure corresponding to OCCP is usually significantly below the cloud-top pressure climatology assumed in the V8 algorithm, the V8.5 derived column amounts have decreased over clouds. The magnitude of the decrease depends on cloud fraction, location, and solar zenith angle.

The effective cloud fraction (fc) derived from the MLER model is used to estimate the Cloud Radiance Fraction (CRF). CRF characterizes the fraction of measured radiation that is scattered by clouds. Mie scattering calculations indicate that the clear and cloudy ozone columns weighted by CRF provides a value very close to what one would from the plane parallel Mie cloud model with the independent pixel approximation to account for mixed scenes. The advantage of the MLER model is that one doesn't need independent knowledge of geometrical cloud fraction to calculate the ozone column accurately in cloudy scenes.

The algorithm also calculates the absorbing Aerosol Index (AI) from the radiance residuals at 360 nm. The AI is useful for tracking global transport of smoke and dust, for it can track these aerosols above and through clouds, as well as over snow/ice covered surfaces. Various studies have indicated that AI is very nearly proportional to the aerosol absorption optical depth at 360 nm. However, the proportionality constant varies with the altitude (of the center of mass) of the aerosol layer- the lower the altitude the smaller the constant. Most aerosols have stronger absorption in the UV than in the visible, including mineral dust from deserts and carbonaceous aerosols containing organic and black carbon. Since the AI is also affected by the spectral dependence of surface albedo caused by sea-glint and water–leaving radiance, and since there are residual errors in the MLER model in estimating Rayleigh scattering in presence of clouds, we recommend that only the AI values larger than +1 should be used for aerosol studies and areas contaminated by sea-glint should be avoided completely. Since absorbing aerosols cause the ozone derived from the basic ozone retrieval algorithm to be overestimated, a parametric relationship based on AI is used to correct the initial retrieved ozone column. This relationship also appears to remove a large portion of errors caused by sea-glint.

Other than the three primary wavelengths mentioned above, the OMTO3 algorithm uses additional wavelengths for quality control and error correction in more restricted geophysical situations. These include correction for ozone profile shape errors at large solar zenith angles using 312.6 nm measurements, and the detection of strong sulfur-dioxide contamination using multiple wavelength pairs. For a more detailed description of the algorithm please refer to the Algorithm Theoretical Basis Document (ATBD) on

http://eospso.gsfc.nasa.gov/eos_homepage/for_scientists/atbd/viewInstrument.php?instrument=13.

Note that V2.1 will be the last version to use this algorithm; the next release of NMTO3-L2 will utilize a new, improved retrieval algorithm based on the Rogers Optimal Estimation method. The new algorithm was recently used to reprocess the OMI dataset as well as datasets from the Nimbus-7 Total Ozone Mapping Spectrometer (TOMS) and the Earth-Probe TOMS instruments.

4. What's New?

V2.0 is the first version of the dataset released through the GES DISC. The previous V1.0 dataset was available through NASA's OMPS science team's web site:

https://ozoneaq.gsfc.nasa.gov/omps

Changes from V1.0 to V2.0 include:

Non science related changes

Nomenclature and Naming Convention

1) The naming convention for the L1B dataset has been changed from TC_SDR_EV_NASA to NMEV-L1B:
    a. TC (Total Column) has been replaced by NM (Nadir Mapper).
    b. NOAA nomenclature (SDR) has been replaced by NASA nomenclature (L1B).
2) All capitalization of names within the file has been replaced by camel casing.
3) Underlines in all names have been eliminated.

Science related changes

1) The V2.1 dataset uses V2.0 of NMEV-L1B as input. The V2.0 L1B provides improved radiance calibration.
2) SurfaceCategory has been added to the AncillaryData group. It is based on the International Geosphere–Biosphere Programme (IGBP) surface classification.
3) GroundPixelQualityFlags and InstrumentQualityFlags have been added to the GeolocationGroup
4) A TrendingData group has been added
    a) QualityFlagsFrequency provides the percent frequency of occurrence for each of the defined Algorithm Quality Flags

The V2.0 file contains swath-based radiance data for the daylit part of one orbit. There are typically 36 cross-track measurements per swath and 400 swatch based observations per orbit.

5. File Naming Convention

The OMPS Nadir Mapper data products use the following file name convention:

OMPS-satellite_sensorproduct-**L**level_**v**m.n_observationDate_productionTime.**h5**

Where:

- satellite = NPP
- sensorproduct = NMTO3
- level = 2
- m.n = algorithm version identifier (m = major, n = minor)
- observationDate = start date of measurements in *yyyymmdd* format
    - *yyyy* = 4-digit year number[2012-current]
    - *mm* = 2-digit month number [01-12]
    - *dd* = 2-digit day number [01-31]
- productionTime = file creation stamp in *yyyy***m***mmdd***t***hhmmss* format

- *hhmmss* = production time [local time]

Filename example:

OMPS-NPP_NMTO3-L2_v2.1_2012m0403t103340_o02243_2017m0223t154258.h5

6. File Format and Structure

NMTO3-L2 data files are provided in the HDF5 format (Hierarchical Data Format Version 5), developed at the National Center for Supercomputing Applications https://www.hdfgroup.org/. These files use the Swath data structure format.

The top-most level in the HDF5 hierarchy of NMTO3-L2 files contains three different directories, one for each type of pixel-dependent data: CalibrationData (containing data used to create calibrated radiances), GeolocationData (containing data to geolocate each pixel, as well as spacecraft location and pointing information), and ScienceData (containing the calibrated radiances, quality flags, and error terms). These three groups are described in more detail in the next section.

7. Data Contents

The data fields most likely to be used by typical users of the NMEV-L1B product are listed below.

Parameter	Group
Date	GeolocationFields
Latitude	GeolocationFields
Longitude	GeolocationFields
BandCenterWavelengths	CalibrationData
SolarFlux	CalibrationData
SolarFluxWavelengths	CalibrationData
ColumnAmountO3	ScienceData
UVAerosolIndex	ScienceData
Reflectivity331	ScienceData

The first OMPS NMEV measurements used to create the NMEV-L1B product were taken on January 28, 2012. Data for February-March 2012 have numerous gaps due to variations in instrument. Regular operations began on April 2, 2012. Note that the OMPS Nadir Mapper conducted high-resolution measurements approximately one day per week from April 2012 to June 2016.

NMTO3-L2 includes the following dimension terms:

Name	long_name	Value
DimAlongTrack	Along-track dimension	400
DimCrossTrack	Across-track dimension	36
DimWavelength		12
DimCorners		4
DimPressureLevel		11

Metadata in NMEV-L1B data files includes attributes whose value is constant for all files and attributes whose value is unique to each individual file. Table 3.2.1 summarizes these global attributes.

Global Attribute	Type	Description
APPName	String	Software name
APPVersion	String	Software version
ArchiveSetName	String	Archive set name for processing
ArchiveSetNumber	Integer*8	Archive set number for processing
Conventions	String	Name of convention(s) for metadata
DATA_QUALITY	Integer	Quality of the data
DOI	String	DOI value
DayNightFlag	String	Identify day or night measurements
EquatorCrossingDate	String	Date of equator crossing
EquatorCrossingLongitude	Real*4	Longitude of equator crossing
EquatorCorssingTime	String	Time of equator crossing
Format	String	Data file format
LocalGranuleID	String	File name
LongName	String	Full product name
OrbitNumber	Integer*8	First orbit number of day
PGEVersion	String	Software version (same as APPVersion)
ProductDateTime	String	Time of file creation
RangeBeginningDateTime	String	Starting date and time of data
RangeEndingDateTime	String	Ending date and time of data
SAMP_TBL	Integer	Number of sample table used to take data
SAMP_TBL_VER	Integer	Version of the sample table used to take data
ShortName	String	Short product name
VersionID	Integer*4	Version ID for this product
VersionNumber	String	Version number for this product
acknowledgement	String	Acknowledgement of data producer
comment	String	Any additional comments
contributor_name	String	Name of data creator
contributor_role	String	Role of data creator
creator_email	String	e-mail address of data creator
creator_institution	String	Organization of data creator
creator_name	String	Name of data creator
creator_type	String	Type of data creator (e.g. person, organization)
date_created	String	Date of file creation
history	String	History of file

id	String	Short product name
institution	String	Producer of data
instrument	String	Instrument making measurements
instrument_vocabulary	String	Source of instrument terms
keywords	String	Identifying keywords
keywords_vocabulary	String	Source of keywords used in metadata
license	String	Source of data information regulations
metadata link	String	Web address for metadata DOI
naming_authority	String	Organization providing naming information
platform	String	Platform for measuring instrument
processing_level	String	Level of data product (e.g. L1B, L2)
program	String	Type of measurement program
project	String	Name of project
publisher_email	String	e-mail address of data publisher
publisher_institution	String	Organization of data publisher
publisher_name	String	Name of data publisher
publisher_type	String	Organization type of data publisher
publisher_url	String	URL of data publisher
references	String	Reference material for data product
source	String	Source of measurement data
summary	String	Any additional summary
time_coverage_end	String	Ending data and time of data
time_coverage_start	String	Starting date and time of data
title	String	Title of data product

8. Products/Parameters

CalibrationData Group

Dataset Name	Description	Dimensions	Units
APrioriLayerO3	A priori ozone profile	DimAlongTrack DimCrossTrack	Dobson Units
CloudPressure	Optical centroid pressure	DimAlongTrack DimCrossTrack	
SurfaceCategory	Surface category	DimAlongTrack DimCrossTrack	
TerrainPressure	Terrain pressure	DimAlongTrack DimCrossTrack	Atmospheres

CalibrationData Group

Dataset Name	Description	Dimensions	Units
Wavelength	Wavelengths input from L1B (note: L1B wavelengths interpolated to match these values)	DimWavelengths	nm

GeolocationData Group

Dataset Name	Description	Dimensions	Units
GroundPixelQualityFlags	Ground pixel quality flag (bit packed)	DimAlongTrack DimCrossTrack	No units
InstrumentQualityFlags	Bit-packed error flags for each pixel	DimAlongTrack DimCrossTrack	No units
Latitude	Ground pixel latitude	DimAlongTrack, DimCrossTrack	Degrees
LatitudeCorner	Ground pixel latitude corners	DimAlongTrack, DimCrossTrack 4	Degrees
Longitude	Ground pixel longitude	DimAlongTrack, DimCrossTrack	Degrees
LongitudeCorner	Ground pixel longitude corners	DimAlongTrack, DimCrossTrack 4	Degrees
RelativeAzimuthAngle	Difference between viewing and solar azimuth angles	DimAlongTrack, DimCrossTrack	Degrees
SecondsinDay	Time when swath measurement was taken (in number of seconds since begging of the day)	DimAlongTrack,	Seconds
ViewingAzimuthAngle	Satellite azimuth of each pixel	DimAlongTrack, DimCrossTrack	Degrees
ViewingZenithAngle	Satellite zenith angle of each pixel	DimAlongTrack, DimCrossTrack	Degrees
SolarAzimuthAngle	Solar azimuth of each pixel	DimAlongTrack, DimCrossTrack	Degrees
SolarBetaAngle	Angles between a geocentric Sun vector and its projection on the NPP orbital plane	DimAlongTrack	No Units
SolarZenithAngle	Solar zenith angle of each pixel	DimAlongTrack, DimCrossTrack	Degrees
SpacecraftAltitude	Spacecraft altitude	DimAlongTrack	Meters
SpacecraftLatitude	Spacecraft Latitude	DimAlongTrack	Degrees
SpacecraftLongitude	Spacecraft Longitude	DimAlongTrack	Degrees
SubSatelliteSolarZenithAngle	Solar zenith angle at subsatellite point	DimAlongTrack	Degrees
Time	TAI93 time of measurement (number of seconds since 1 January 1993)	DimAlongTrack	Seconds
UTC_CCDSDS_A	Twenty-seven character UTC date-and-time string	DimAlongTrack	No Units
GroundPixelQualityFlags	SAA, eclipse, Sun glint, terrain type flags	DimAlongTrack, DimCrossTrack	No Units

Definition of bit-packed GroundPixelQualityFlags

0-3	Unused		
4-5	SAA Flag	WARNING	Indicates location of spacecraft w.r.t. SAA 0 = outside SAA boundaries 1 = <5% of nominal maximum SAA effect 2 = between 5% and 40% of nominal maximum SAA effect 3 = >40% of nominal maximum SAA effect
6-19	Unused		
20	Maneuver Flag	WARNING	Indicates a spacecraft attitude maneuver was in progress during the measurement
21	Attitude Threshold Flag	WARNING	Indicates any of the 3 geodetic spacecraft attitude Euler angles exceeds a defined threshold
22-31	Unused		

Definition of InstrumentQualityFlags

0-7	Unused		
8	Eclipse Flag	WARNING	Indicates ground pixel is within umbra or penumbra of the moon
9-15	Unused		

ScienceData Group

Dataset Name	Description	Dimensions	Units
AlgorithmFlags		DimAlongTrack, DimCrossTrack	No units
ColumnAmountO3	Final Total column ozone amounts	DimAlongTrack, DimCrossTrack	Dobson Units
Layer efficiency		DimAlongTrack, DimCrossTrack	No units
MeasurementQualityFlags		DimAlongTrack, DimCrossTrack	No units
NValue	N value [-100*log10(normalized radiance)]	DimAlongTrack, DimCrossTrack	No units
NValueAdjustment	Soft calibration applied to N values	DimAlongTrack, DimCrossTrack	No units
O3BelowCLoud	Estimate of ozone amount below cloud	DimAlongTrack, DimCrossTrack	Dobson Units
QualityFlags		DimAlongTrack, DimCrossTrack	No Units
RadiativeCloudFraction		DimAlongTrack, DimCrossTrack	Fraction between 0 and 1
Reflectivity331	331 nm reflectivity	DimAlongTrack, DimCrossTrack	Fraction

Reflectivity360	360 nm reflectivity	DimAlongTrack, DimCrossTrack	Fraction
SO2index	Estimate of SO2 contamination	DimAlongTrack, DimCrossTrack	Dobson Units
Sensitivity	Sensitivity of N value to change in ozone	DimAlongTrack, DimCrossTrack	1 / Dobson Units
StepOneO3	Estimate of total ozone from step 1 of algorithm	DimAlongTrack, DimCrossTrack	Dobson Units
StepTwoO3	Estimate of total oozne from step 2 of algorithm	DimAlongTrack, DimCrossTrack	Dobson Units
UVAerosolIndex	Aerosol Index	DimAlongTrack, DimCrossTrack	No units
dN_dR	Sensitivity of N value to change in reflectivity	DimAlongTrack, DimCrossTrack	
dN_dT	Sensitivity of N value to change in temperature	DimAlongTrack, DimCrossTrack	1 / Degrees
Fc			
Radcl			
radgr			

9. References

Pawan K. Bhartia and Charles W. Wellemeyer, OMI Algorithm Theoretical Basis Document, Volume II, Chapter 2, https://eospso.nasa.gov/atbd-category/49.

Kramarova, N., E. Nash, P. Newman, P. K. Bhartia , R. McPeters , D. Rault , C. Seftor , P. Q. Xu, and G. Labow (2013), Measuring the Antarctic ozone hole with the new Ozone Mapping and Profiler Suite (OMPS), Atmos. Chem. Phys., 14, 2353-2361, doi:10.5194/acp-14-2353-2014, 2014.